

DIO6905

2 A, Synchronous, Step-Down Converter with Low 15 μ A Quiescent Current

Features

- Input voltage range from 2.3 V to 5.5 V
- Up to 2 A output current
- Low quiescent current: 15 μ A
- Output adjustable from 0.6 V
- 1.65 MHz typical switching frequency at $T_J = 25^\circ\text{C}$
- EN for power sequencing
- Low $R_{DS(\text{ON})}$ for internal switches (Top / Bottom): 120 m Ω / 80 m Ω
- Output discharge function
- 100% duty cycle in drop
- Hiccup for short-circuit protection (SCP)
- Stable with low ESR output ceramic capacitors
- Available in SOT563 and DFN1.6*1.6-6 packages

Descriptions

The DIO6905 is a high-efficiency, 1.65 MHz synchronous step-down DC/DC converter with power MOSFETs integrated. It can achieve an output current of 2 A under an input voltage of 2.3 V to 5.5 V and has good load and line regulation. The output voltage can be adjusted from 0.6 V.

The DIO6905 adopts the COT architecture to achieve fast transient responses and simplifies loop stability. In addition, it operates full protection features including cycle-by-cycle current limit and thermal shutdown.

The DIO6905 packaged in SOT563 and DFN1.6*1.6-6 uses fewer external components, enabling a cost-effective solution.

Applications

- Wireless/Networking cards
- Portable and mobile devices
- Battery-powered devices
- Low-voltage I/O system power
- Solid-state drives (SSDs)

Ordering Information

Ordering Part No.	Top Marking	MSL	RoHS	T_A	Package	
DIO6905SH3	W5A	3	Green	-40 to 105°C	SOT563	Tape & Reel, 5000
DIO6905FT6	YW5A	1	Green	-40 to 105°C	DFN1.6*1.6-6	Tape & Reel, 3000

Pin Assignments

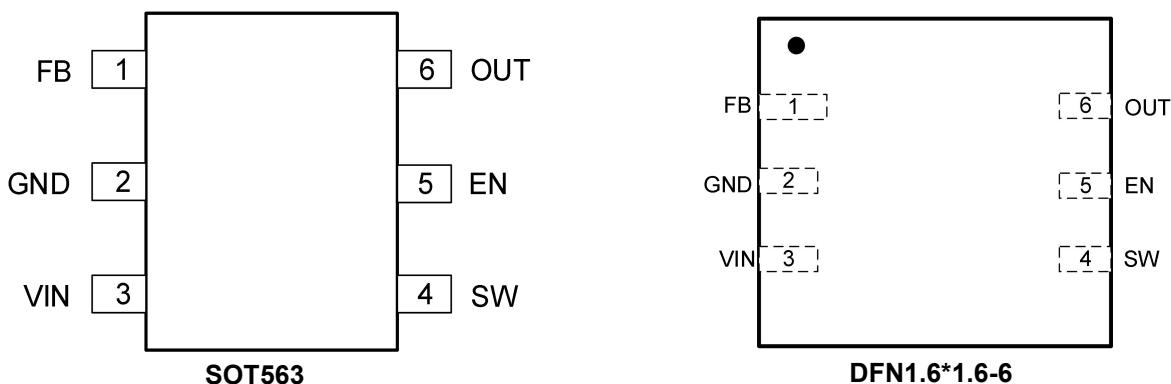


Figure 1. Pin assignment (Top view)

Pin Definitions

Pin Name	Description
FB	Feedback. An external resistor divider from the output to GND tapped to FB sets the output voltage.
GND	Power ground.
VIN	Supply voltage. The DIO6905 operates from a 2.3 V to 5.5 V unregulated input. A decoupling capacitor is required to prevent large voltage spikes from appearing at the input.
SW	Output switching node. SW is the drain of the internal high-side P-channel MOSFET. Connect the inductor to SW to complete the converter.
EN	On / Off control.
OUT	Output voltage power rail and input sense for the output voltage. Connect the load to OUT. An output capacitor is required to decrease the output voltage ripple.

Absolute Maximum Ratings

Stresses beyond those listed under the Absolute Maximum Rating table may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other condition beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Symbol	Parameter	Rating	Unit
V_{IN}	Supply voltage	6.0	V
V_{SW}	Switching voltage	-0.3 (-5 V for < 20 ns) to 6.0 (8 V for < 20 ns or 10 V for < 10 ns)	V
All other pins		-0.3 to 6.0	V
T_J	Junction temperature range	150	°C
T_L	Lead temperature range	260	°C
P_D	Continuous power dissipation ($T_A = 25^\circ\text{C}$)	1	W
T_{STG}	Storage temperature	-65 to 150	°C
ESD	Human body mode	±2000	V
Latch-up		200	mA

Recommend Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. DIOO does not recommend exceeding them or designing to absolute maximum ratings.

Symbol	Parameter	Rating	Unit
V_{IN}	Supply voltage	2.3 to 5.5	V
T_J	Operating junction temperature range	-40 to 125	°C
θ_{JA}	Package thermal resistance	130	°C/W
		60	
θ_{JC}	DFN1.6*1.6-6	100	°C/W
		50	

Electrical Characteristics

$V_{IN} = 3.6 \text{ V}$, $T_A = 25^\circ\text{C}$, unless otherwise specified.

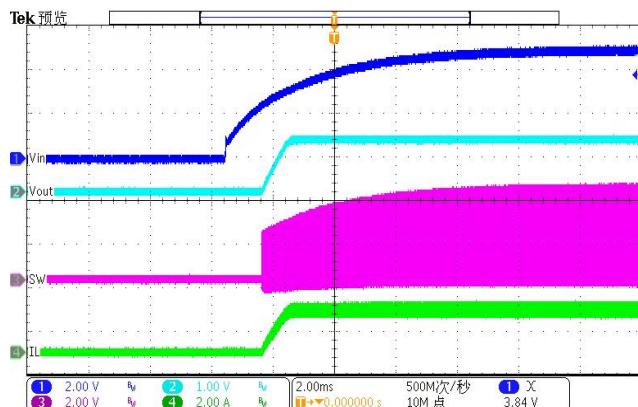
Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{FB}	Feedback voltage	$2.3 \text{ V} \leq V_{IN} \leq 5.5 \text{ V}$, $T_J = 25^\circ\text{C}$	594	600	606	mV
		$T_J = -40^\circ\text{C}$ to 125°C ⁽²⁾	588		612	
V_{UVLO}	Undervoltage lockout threshold rising			2.1	2.3	V
	Undervoltage lockout threshold hysteresis			50		mV
V_{IL}	EN input logic low voltage				0.4	V
V_{IH}	EN input logic high voltage		1.2			V
I_{LKG_EN}	EN input current	$V_{EN} = 2 \text{ V}$		2		μA
		$V_{EN} = 0 \text{ V}$		0		μA
I_{SD}	Supply current (shutdown)	$V_{EN} = 0 \text{ V}$, $T_J = 25^\circ\text{C}$		0	1	μA
I_Q	Supply current (quiescent)	$V_{EN} = 2 \text{ V}$, $V_{FB} = 0.63 \text{ V}$, $V_{IN} = 3.6 \text{ V}$, 5 V , $T_J = 25^\circ\text{C}$		15	30	μA
I_{FB}	Feedback current	$V_{FB} = 0.63 \text{ V}$		50	100	nA
R_{DSON_P}	P-FET switch on resistance			120		$\text{m}\Omega$
R_{DSON_N}	N-FET switch on resistance			80		$\text{m}\Omega$
R_{DIS}	Output discharge resistor	$V_{EN} = 0 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$		1		k Ω
I_{LKG_P}	Switch leakage current	$V_{EN} = 0 \text{ V}$, $V_{IN} = 6 \text{ V}$, $V_{SW} = 0 \text{ V}$ and 6 V , $T_J = 25^\circ\text{C}$		0	1	μA
I_{LIM_P}	P-FET peak current limit	Sourcing	2.4			A
I_{LIM_N}	N-FET valley current limit	Sourcing, valley current limit		1.6		A
ZCD	Zero current cross detection			0		mA
t_{ON}	On-time	$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$		145		ns
		$V_{IN} = 3.6 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$		202		
f_s	Switching frequency	$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$, $I_{OUT} = 500 \text{ mA}$, $T_J = 25^\circ\text{C}$ ⁽¹⁾	1300	1650	2000	kHz
		$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$, $I_{OUT} = 500 \text{ mA}$, $T_J = -40^\circ\text{C}$ to 125°C ⁽¹⁾	1230	1650	2070	kHz
$t_{MIN-OFF}$	Minimum off-time			60		ns
t_{MIN-ON}	Minimum on-time ⁽¹⁾			60		ns
t_{SS-ON}	Soft-start time	V_{OUT} rise from 10% to 90%		0.6		ms
T_{SD}	Thermal shutdown ⁽²⁾			160		°C
T_{HYST}	Thermal hysteresis ⁽²⁾			30		°C

Note:

- (1) Guaranteed by characterization.
- (2) Guaranteed by design.
- (3) Specifications subjects to change without notice.

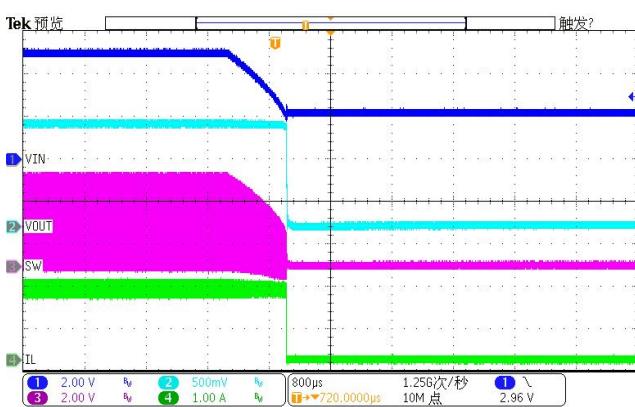
Typical Performance Characteristic

$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$, $L = 1.0 \mu\text{H}$, $C_{IN} = C_{OUT} = 10 \mu\text{F}$, $T_A = 25^\circ\text{C}$, unless otherwise specified.



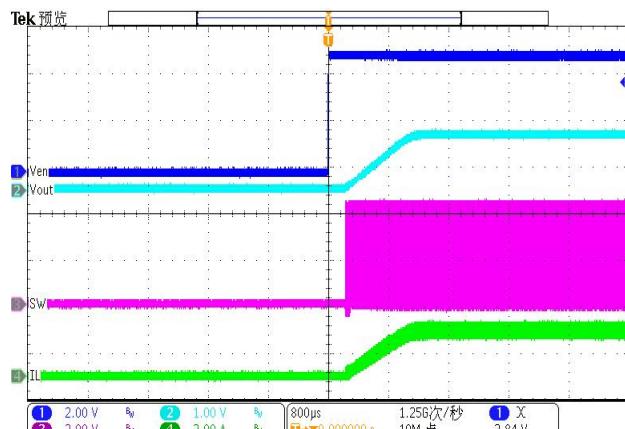
$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$ with 2 A load

Figure 2. V_{IN} start



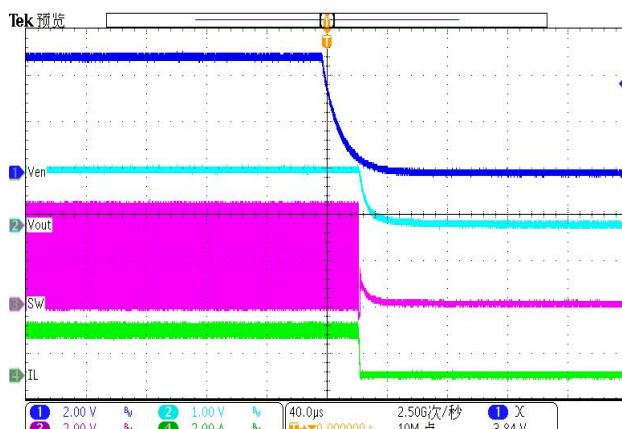
$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$ with 2 A load

Figure 3. V_{IN} drop



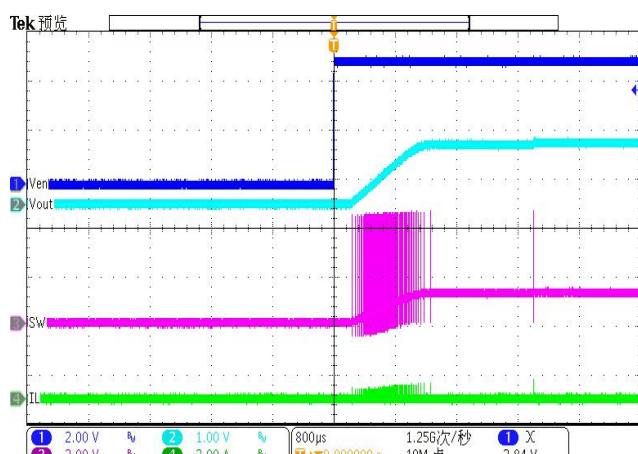
$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$ with 2 A load

Figure 4. V_{EN} start-up



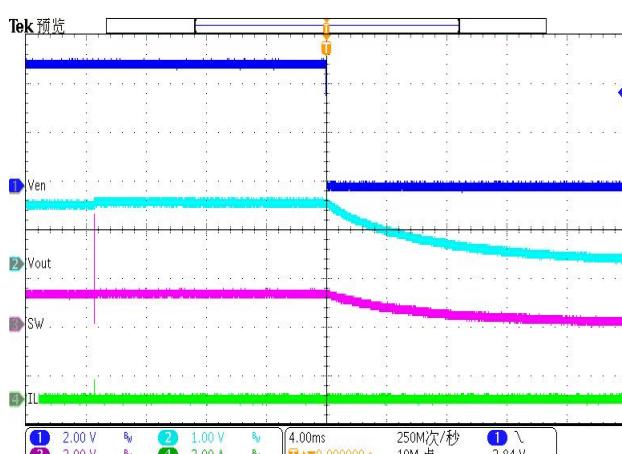
$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$ with 2 A load

Figure 5. V_{EN} drop



$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$, without load

Figure 6. V_{EN} start-up



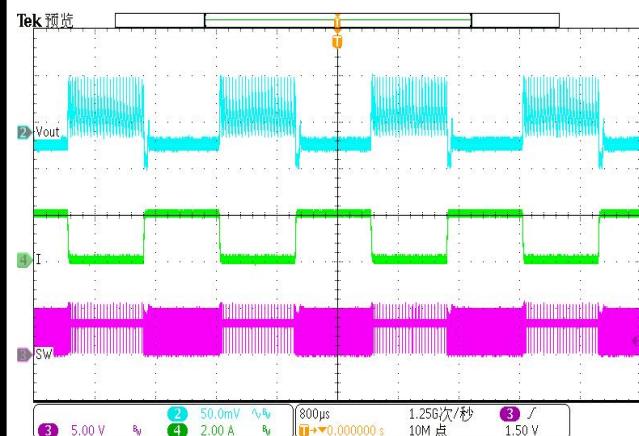
$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$, without load

Figure 7. V_{EN} drop

2 A, Synchronous, Step-Down Converter with Low 15 μ A Quiescent Current

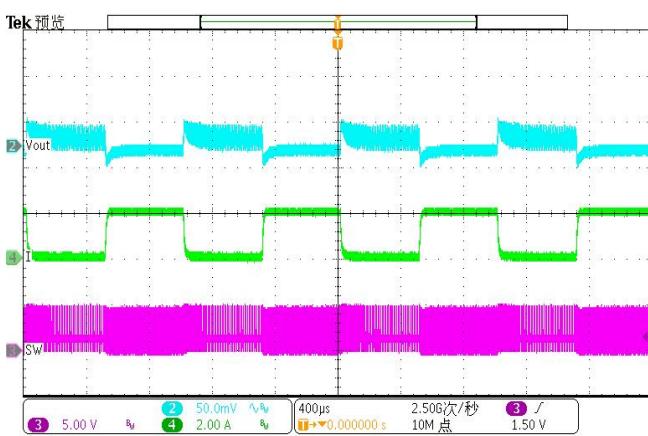


DIO6905



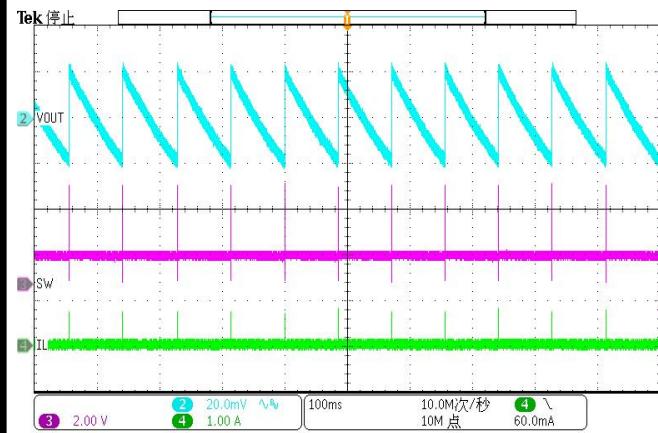
$V_{IN} = 5 \text{ V}$, $V_{OUT} = 3.3 \text{ V}$, $0 \text{ A} \sim 2 \text{ A}$

Figure 8. Load transient



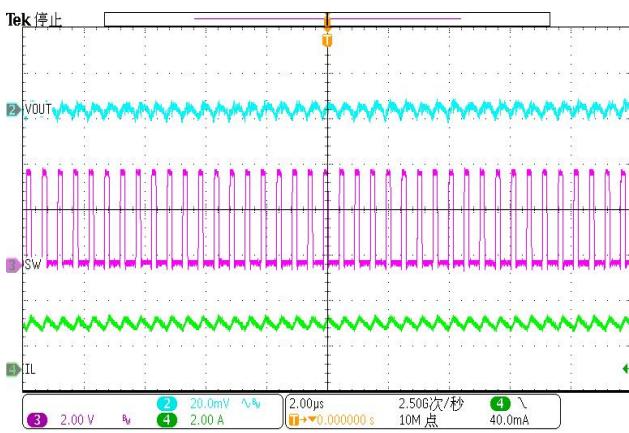
$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$, $0 \text{ A} \sim 2 \text{ A}$

Figure 9. Load transient



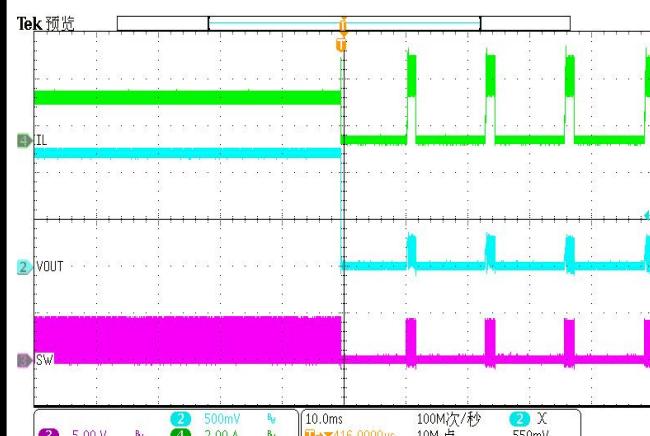
$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$, No Load

Figure 10. Ripple



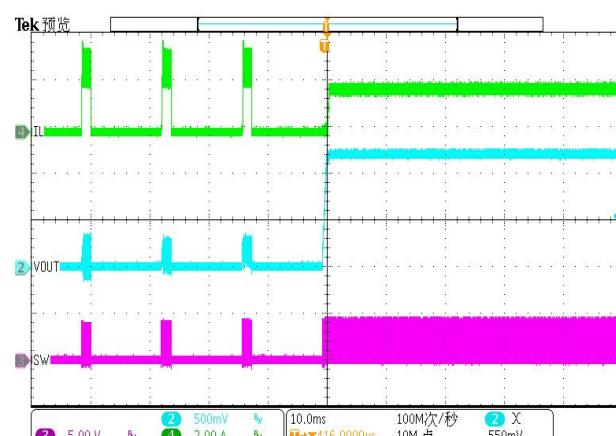
$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$, Load = 2 A

Figure 11. Ripple



$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$, $2 \text{ A} \rightarrow \text{short}$

Figure 12. Short-circuit protection



$V_{IN} = 5 \text{ V}$, $V_{OUT} = 1.2 \text{ V}$, short $\rightarrow 2 \text{ A}$

Figure 13. Short-circuit recovery

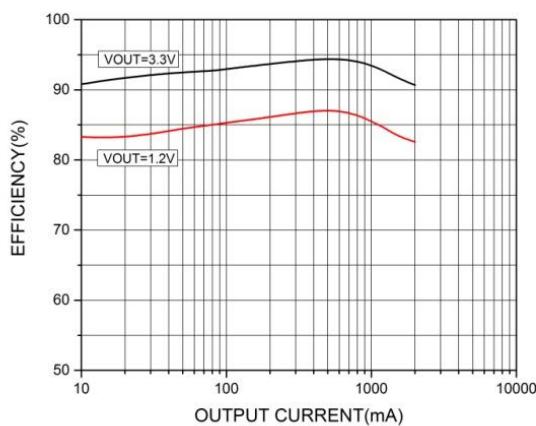


Figure 14. Efficiency vs. output current

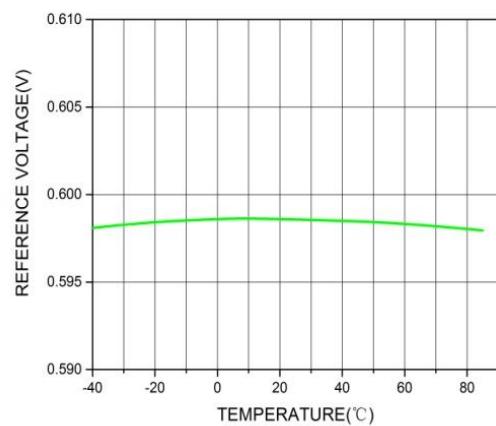
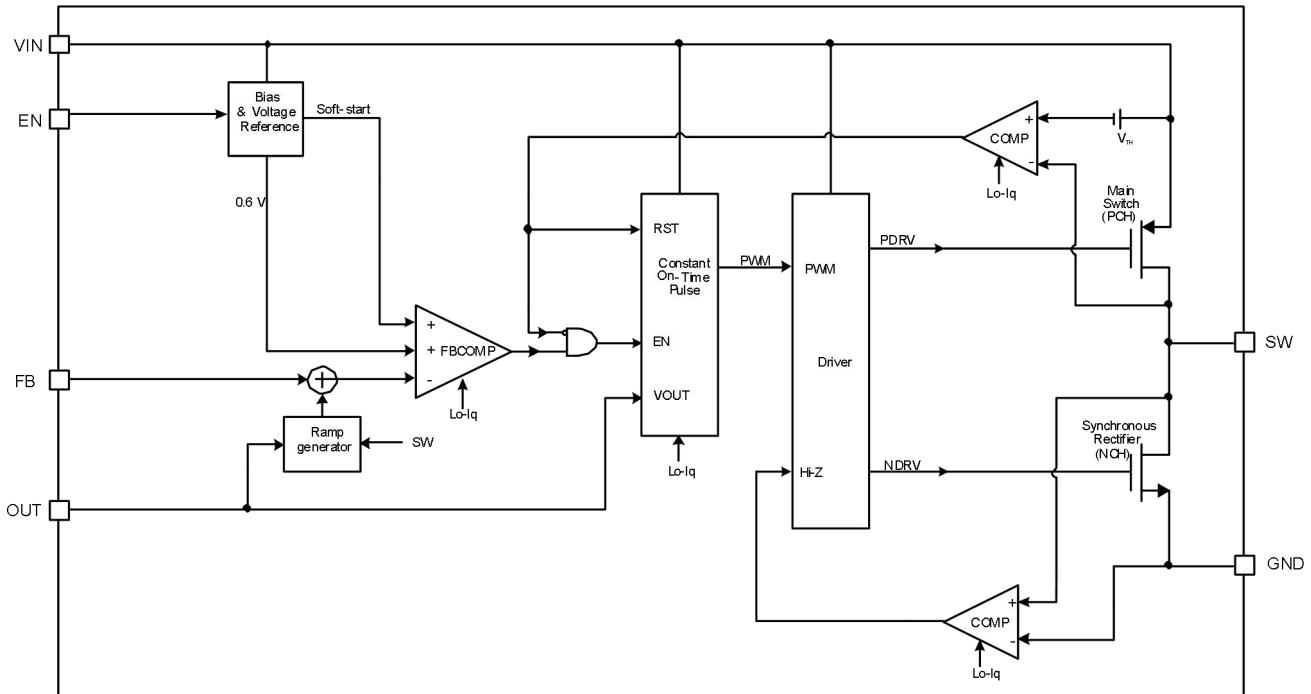
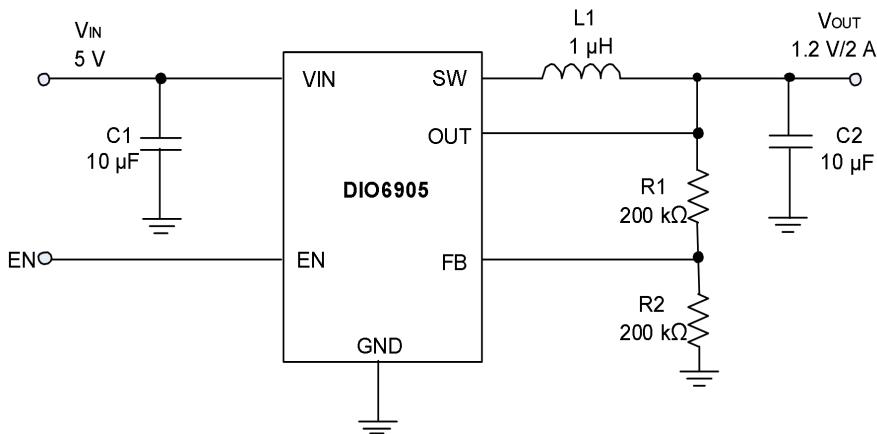


Figure 15. Reference voltage vs. temperature

Block Diagram



Typical Application



Detailed Description

The DIO6905 uses constant on-time control with input voltage feed-forward to stabilize the switching frequency over its full input voltage range. It achieves 2 A of output current from a 2.3 V to 5.5 V input voltage range with excellent load and line regulation. The output voltage can be regulated as low as 0.6 V.

Constant-on-time control

When compared to fixed-frequency PWM control, COT control offers a simpler control loop and faster transient response. By using input voltage feed-forward, the DIO6905 maintains a nearly constant switching frequency across the input and output voltage ranges. The switching pulse on-time can be estimated with Equation (1):

$$t_{ON} = \frac{V_{OUT}}{V_{IN}} * 0.606 \mu\text{s} \quad (1)$$

To prevent inductor current runaway during the load transient, the DIO6905 has a fixed minimum-off-time of 60 ns.

Sleep mode operation

The DIO6905 adopts sleep mode to achieve high efficiency under extremely light load condition. In such sleep mode, most of the circuitry is turned off, except the EA (error amplifier) and the PWM comparator, which results in minimum operation current as shown in Figure 16.

When the loading gets lighter, and the ripple of the output voltage is bigger, the DIO6905 enters sleep mode. Under sleep mode situation, the valley of the FB pin voltage is regulated to the internal reference voltage. Therefore, the average output voltage is slightly higher than the output voltage in DCM or CCM. The on-time pulse in sleep mode is around 40% larger than that in DCM or CCM mode. Figure 17 shows the average FB pin voltage relationship with the internal reference in sleep mode.

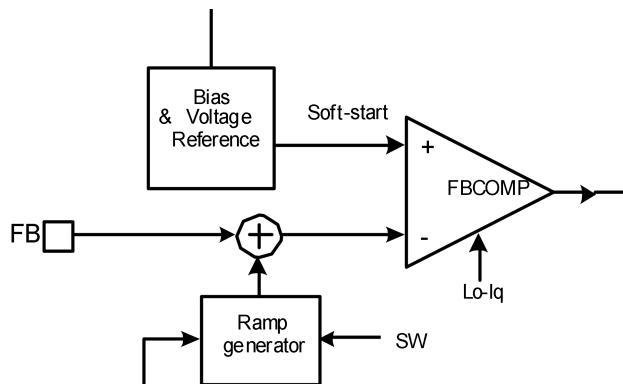


Figure 16. Operation blocks in sleep mode

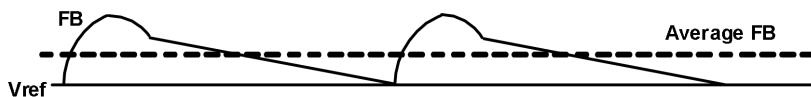


Figure 17. FB Average voltage in sleep mode

Enable (EN)

When the input voltage is greater than the undervoltage lockout (UVLO) threshold (typically 2.1 V), the DIO6905 can be enabled by pulling EN higher than 1.2 V. Leaving EN floating or pulling it down to ground disables the DIO6905. There is an internal 1 M Ω resistor from EN to ground.

When the DIO6905 is disabled, the part goes into output discharge mode automatically. The internal discharge MOSFET provides a resistive discharge path for the output capacitor.

Soft-start

The DIO6905 has a built-in soft-start that ramps up the output voltage at a constant slew rate that avoids overshooting at startup. The soft-start time is typically approximately 0.6 ms.

Current limit

The DIO6905 has a 2.4 A current limit for the HS-FET. When the HS-FET hits its current limit, the DIO6905 enters current limit mode until the current drops to prevent the inductor current from rising and possibly damaging the components.

Short-circuit protection and recovery

The DIO6905 enters short-circuit protection (SCP) mode when it reaches the current limit and attempts to recover from the short-circuit by entering hiccup mode. In SCP, the DIO6905 disables the output power stage, discharges the soft-start capacitor, and then enacts a soft-start procedure. If the short-circuit condition still holds after the soft-start ends, the DIO6905 repeats this cycle until the short-circuit disappears and the output rises back to regulation levels.

Application Information

Setting the output voltage

The external resistor divider sets the output voltage. Select the feedback resistor R1 which reduces the V_{OUT} leakage current, typically between 40 k Ω to 200 k Ω . There is not strict requirement on the feedback resistor. R1 > 10 k Ω is reasoned for most application. R2 can be calculated with Equation (2):

$$R2 = \frac{R1}{\frac{V_{OUT}}{0.6} - 1} \quad (2)$$

The feedback circuit is shown as Figure 18:

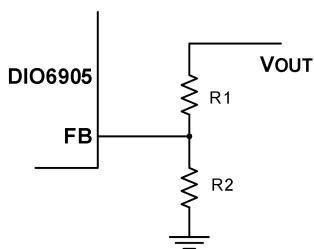


Figure 18. Feedback network

Table 1 lists the recommended resistor's values for common output voltages:

Table 1. Resistor values for common output voltages

V_{OUT} (V)	R1 (k Ω)	R2 (k Ω)
1.0	200 (1%)	300 (1%)
1.2	200 (1%)	200 (1%)
1.8	200 (1%)	100 (1%)
2.5	200 (1%)	63.2 (1%)
3.3	200 (1%)	44.2 (1%)

Selecting the inductor

Most applications work best with a 1 μ H to 2.2 μ H inductor. For highest efficiency, choose an inductor with a DC resistance less than 15 m Ω .

A high-frequency switch-mode power supply with a magnetic device has strong electronic magnetic inference. Any unshielded power inductors should be avoided. Metal alloy or multiplayer chip power inductors are ideal shielded inductors for the application because they can decrease the influence effectively. Table 2 lists some recommended inductors.

Table 2. Recommended inductors

Manufacturer P/N	Inductance (μ H)	Manufacturer
PIFE25201B-1R0MS	1.0	CYNTEC CO. LTD.
1239AS-H-1R0M	1.0	Tokyo
744 777 002	2.2	Wurth

For most designs, the inductance value can be estimated with Equation (3):

$$L_1 = \frac{V_{OUT} * (V_{IN} - V_{OUT})}{V_{IN} * \Delta I_L * f_{osc}} \quad (3)$$

Where ΔI_L is the inductor ripple current.

Choose an inductor current to be approximately 30% of the maximum load current. The maximum inductor peak current can be calculated with Equation (4):

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2} \quad (4)$$

Selecting the input capacitor

The input current to the step-down converter is discontinuous, and therefore requires a capacitor to supply the AC current to the step-down converter while maintaining the DC input voltage. Use low-ESR capacitors for the best performance. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR values and small temperature coefficients. For most applications, a 10 μ F capacitor is sufficient. Higher output voltages may require a 22 μ F capacitor to increase system stability.

The input capacitor requires an adequate ripple current rating since it absorbs the input switching current. Estimate the RMS current in the input capacitor with Equation (5):

$$I_{C1} = I_{LOAD} * \sqrt{\frac{V_{OUT}}{V_{IN}} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right)} \quad (5)$$

The worst-case scenario occurs at $V_{IN} = 2 V_{OUT}$, shown in Equation (6):

$$I_{C1} = \frac{I_{LOAD}}{2} \quad (6)$$

For simplification, choose an input capacitor with RMS current rating greater than half of the maximum load current.

The input capacitor can be electrolytic, tantalum, or ceramic. When using electrolytic or tantalum capacitors, add a small, high-quality, 0.1 μ F ceramic capacitor as close to the IC as possible. When using ceramic capacitors, ensure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at the input. The input voltage ripple caused by capacitance can be estimated with Equation (7):

$$\Delta V_{IN} = \frac{I_{LOAD}}{f_S * C_1} * \frac{V_{OUT}}{V_{IN}} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (7)$$

Selecting the output capacitor

The output capacitor (C2) stabilizes the DC output voltage. Ceramic capacitors are recommended. Use low ESR capacitors to limit the output voltage ripple. Estimate the output voltage ripple with Equation (8):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S * L_1} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right) * \left(R_{ESR} + \frac{1}{8 * f_S * C_2}\right) \quad (8)$$

Where L_1 is the inductor value and R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor.

When using ceramic capacitors, the capacitance dominates the impedance at the switching frequency, and causes most of the output voltage ripple. For simplification, the output voltage ripple can be estimated with Equation (9):

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 * f_s^2 * L_1 * C_2} * (1 - \frac{V_{OUT}}{V_{IN}}) \quad (9)$$

For tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated with Equation (10):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_s * L_1} * (1 - \frac{V_{OUT}}{V_{IN}}) * R_{ESR} \quad (10)$$

The characteristics of the output capacitor also affect the stability of the regulation system.

PCB Layout Recommendation

Efficient PCB layout is critical for stable operation. For the high-frequency switching converter, a poor layout design can result in poor line or load regulation and stability issues. For best results, refer to Figure 19 and follow the guidelines below.

- (1) Place the high-current paths (GND, IN, and SW) as close to the device as possible with short, direct, and wide traces.
- (2) Keep the input capacitor as close to IN and GND as possible.
- (3) Place the external feedback resistors next to FB.
- (4) Keep the switching node SW short and away from the feedback network.
- (5) Keep the V_{OUT} sense line as short as possible or keep it away from the power inductor and the surrounding inductors.

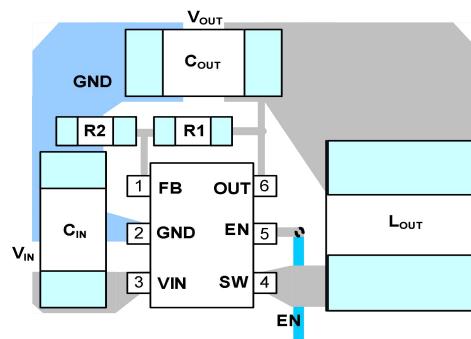
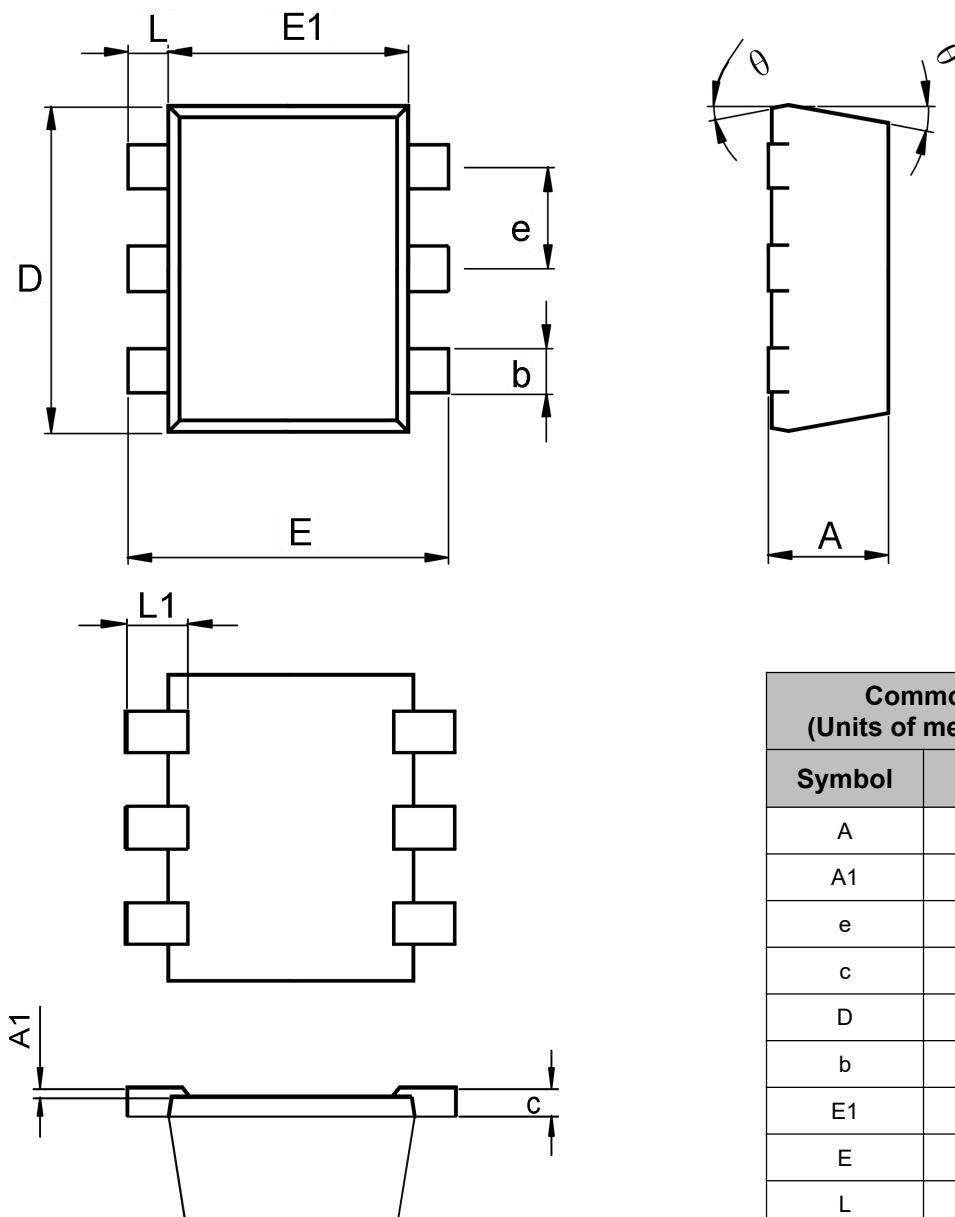


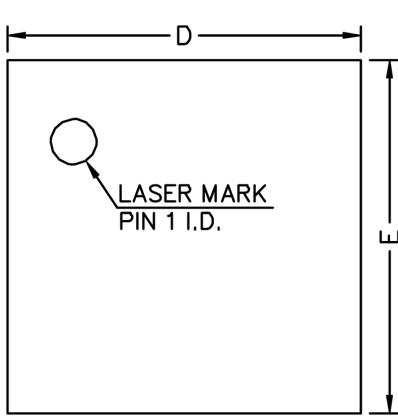
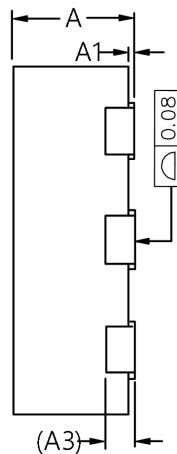
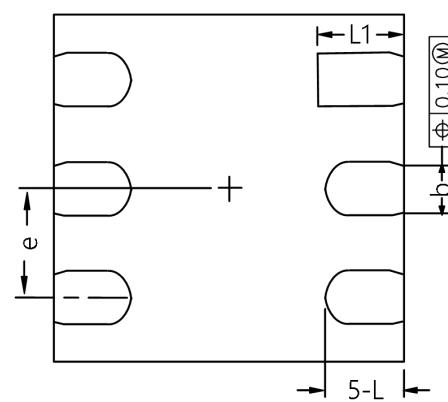
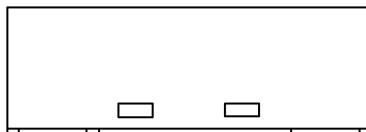
Figure 19. Two ends of input decoupling capacitor close to pin 2 and pin 3

Physical Dimensions: SOT563



Common Dimensions (Units of measure = Millimeter)		
Symbol	Min	Max
A	0.525	0.600
A1	0.000	0.050
e	0.450	0.550
c	0.090	0.180
D	1.500	1.700
b	0.170	0.270
E1	1.100	1.300
E	1.500	1.700
L	0.100	0.300
L1	0.200	0.400
θ	9° REF	

Physical Dimensions: DFN1.6*1.6-6


TOP VIEW

SIDE VIEW

BOTTOM VIEW

SIDE VIEW

Common Dimensions (Units of measure = Millimeter)			
Symbol	Min	Nom	Max
A	0.50	0.55	0.60
A1	0.00	0.02	0.05
A3	0.127 REF		
b	0.20	0.25	0.30
D	1.55	1.60	1.65
E	1.55	1.60	1.65
e	0.40	0.50	0.60
L	0.35	0.40	0.45
L1	0.30	0.35	0.40



CONTACT US

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For additional product information or full datasheet, please contact our sales department or representatives.